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# (54) Random pulse type radar apparatus

(57) A random pulse type radar apparatus sends out as an output signal a spectrum spread radio wave including a pseudo random signal-less period and receives echoes in this signal-less period to thereby significantly reduce transmission peak power. The random pulse type radar apparatus comprises a transmitter for generating a hybrid type spectrum spread signal by simultaneously using two kinds of modulations which are phase shift keying modulation for selecting a phase of a transmission radio wave in accordance with a pseudo noise digital code and outputting the transmission wave, and time hopping modulation for stopping transmission of a radio wave at random in accordance with the pseudo noise digital code; a receiving unit for selectively detecting an echo of a transmission signal radio wave, generated by the transmitter, from a target with a time delay; at least one a common antenna unit for use both for transmission and reception or antenna units installed close to each other and respectively serving single functional units; and a reception control unit for stopping an action of the receiving unit in a time zone in which the transmitter is outputting radio waves in accordance with the time hopping modulation, whereby a spatial distribution of an intensity of an echo of a transmitted radio wave is measured through computation of a cross-correlation function of a transmission signal and a reception signal.

FIG. 1

-PPP-PP-----N-NN-N--P-NNNPN----P--PN--N-N---P-NP-PNPN-NN-PP----NNN-PP--N-P-N---P
-N-P---P-NPP--N--N-N---P--PNP---P-PNN-PN-P-PNP-

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## Description

[0001] The present invention relates to a random pulse type radar apparatus for use in vessels, airplanes, automobiles, missiles and so forth.

[0002] A conventional typical pulse radar apparatus mainly comprises a transmitter which transmits electromagnetic pulse wave energy at given time intervals, and a receiving unit which continuously monitors echo energy of the transmitted energy.

[0003] Because the monitorable distance range of this system is a half the distance acquired by dividing the propagation speed of radio waves by the time interval of output pulses, this system cannot detect echo signals from a target which is located at a greater distance than this monitorable range.

[0004] This necessitates that the intensity of the output radio waves should be powerful enough to be dangerous to human bodies, such as radiation at a very close range. In this respect, radar usage has been managed through the license system.

[0005] A CW radar, which continuously sends out transmission radio waves and utilizes interference of the radio waves with their echoes from a target, has been put to a practical use. While the CW radar is mainly used to measure the moving speed of a target, the target position can be measured by additionally using frequency wobble. The CW radar is hardly used except for a special application.

[0006] A pulse compression radar apparatus of the type that sends out a chirped pulse signal, which is one type of spectrum spread signal, or a BPSK signal of a digital code like a barker code, as an output signal in a short period of time is also used for a special application. This radar apparatus does not differ essentially from the typical pulse radar, and suffers a limited effect of reducing the peak power. In a case of using a BPSK signal, for example, if one tries to reduce the peak power by increasing the transmission time, physical measurement of echoes from a target at a very close range is not possible due to the short reciprocation time of radio waves (see Figures 6 and 7).

[0007] As pleasure-boats become popular, a radar apparatus which can be used without any danger and special knowledge is strongly demanded from a viewpoint of preventing sea accidents. Such a radar apparatus is not actually available on the market because there are no adequate technical schemes.

[0008] It is known that the precision of measuring the distance by a radar becomes higher in proportion to the band width of radio waves that are generally used.

[0009] In the field of radio communication, the direct sequence (DS) system which employs PSK (Phase Shift Keying) modulation by using recursive code sequences and the frequency hopping (FH) system which switches transmission frequencies at a high speed have already been used widely as schemes of generating wide-band radio waves.

[0010] When radio waves of those systems are adapted for a radar usage, the peak of the transmission radio waves becomes minimum but the radio waves are output continuously. In a case of a radar apparatus in which its antenna is used as both the transmission antenna and reception antenna, however, masking of radio waves by the transmission signals makes it substantially impossible to receive very weak echoes.

[0011] Accordingly, it is an object of the present invention to significantly reduce transmission peak power by employing a system, which is disclosed in Japanese Patent No. 2655374, entitled "Spectrum Spread Communication Equipment", by the same applicant as that of this invention and which sends out as an output signal a spectrum spread radio wave including a "signal-less period" set at a pseudo random and receives echoes in this "signal-less period".

[0012] A random pulse type radar apparatus according to this invention comprises a transmitter for generating a hybrid type spectrum spread signal by simultaneously using two kinds of modulations which are phase shift keying (PSK) modulation for selecting a phase of a transmission radio wave in accordance with a pseudo noise digital code and outputting the transmission wave, and time hopping modulation for stopping transmission of a radio wave at random in accordance with the pseudo noise digital code; a receiving unit for selectively detecting an echo of a transmission signal radio wave, generated by the transmitter, from a target with a time delay; at least one a common antenna unit for use both for transmission and reception or antenna units installed close to each other and respectively serving single functional units; and a reception control unit for stopping an action of the receiving unit in a time zone in which the transmitter is outputting radio waves in accordance with the time hopping modulation, whereby a spatial distribution of an intensity of an echo of a transmitted radio wave is measured through computation of a cross-correlation function of a transmission signal and a reception signal.

[0013] The invention, together with objects and advantages thereof, may best be understood by reference to the following description of the presently preferred embodiments together with the accompanying drawings in which:

Figure 1 shows a time sequence consisting of three kinds of modulation states of a positive phase (P), a negative phase (N) and no signal (-) according to one embodiment of this invention;

Figure 2 depicts a circuit for generating a time sequence consisting of three kinds of modulation states of a positive phase (P), a negative phase (N) and no signal (-) according to one embodiment of this invention;

Figure 3 is a block diagram showing the simplest constitution that accomplishes the function of this embodiment;

Figure 4 is a block diagram showing a constitution in a case where the output signal of a receiver according to this embodiment is compensated through digital processing;

Figure 5 exemplifies the constitution of a transmission signal according to another embodiment of this invention wherein FSK (Frequency Shift Keying) is used instead of PSK to construct the transmission signal;

Figure 6 is an explanatory diagram of a conventional pulse compression radar of a linear frequency modulation system; and

Figure 7 is an explanatory diagram of a conventional coded pulse radar.

[0014] The constitution and operation of a preferred embodiment of the present invention will now be described referring to Figures 1 through 5.

[0015] Figures 1 and 2 exemplify a time sequence consisting of three kinds of modulation states of a positive phase (P), a negative phase (N) and no signal (-) and a circuit for generating the time sequence, both being similar to those disclosed in Japanese Patent No. 2655374 entitled "Spectrum Spread Communication Equipment".

[0016] The apparatus comprises two shift registers SR1,SR2 coupled to a local clock source which generates a clock signal CLOCK, as shown. Two bit parallel data is input into and shifted along the shift registers SR1,SR2, in response to the clock signal CLOCK.

[0017] An XOR gate 1 is coupled to the last two bits of the shift register SR1 to determine the logical XOR of the data therein. This is fedback to the input of the shift register SR1 as well as to an output assigning circuit generally designated 10. Similarly, the last four bits of the shift register SR2 are logically XORed using respective XOR gates 2,3,4 to produce a single output bit which is fedback to the input of the shift register SR2 and the output assigning circuit 10.

[0018] The output assigning circuit 10 includes an AND gate 14 and a NOR gate 15 which are coupled to the XOR gates 1,4 as shown. The output of the AND gate 14 is coupled to a plus bit output 11, which is used to control generation of the positive phase modulation states (P), whereas the output from the NOR gate 15 is coupled to a minus bit output 12, which is used to control generation of the negative phase modulation states (N).

[0019] A second NOR gate 16 is coupled to the output of the AND gate 14 and the NOR gate 15 to produce the signal-less output 13, which is used to control generation of the no signal modulation state (-).

[0020] In a case of using this time sequential signals as transmission radio waves of a radar, approximately a half of 127 chip codes are located in a signal-less period where transmission of a radio wave is stopped and detection of coming radio waves is possible (this period will be hereinafter called "window").

[0021] As apparent from Figure 1, this window is distributed at a pseudo random, so that about a half the energy of each echo can always be observed through this window in this example.

[0022] It is obvious that the aperture rate of this window can be adjusted almost arbitrarily by controlling the mixing ratio of signal-less segments in the time sequential signal in Figure 1.

[0023] Figure 3 exemplifies the simplest constitution that accomplishes the above-described function.

[0024] The apparatus of Figure 3 includes a transmitter 20 which has an output coupled to an antenna unit 21 via a switch 22. The switch 22 is also coupled to a receiver 23 to transfer any received signals from the antenna unit 21 to the receiver 23. The receiver 23 includes a reception control unit coupled to a receiving unit 25 which is in turn coupled to a correlation detector 26. The reception control unit 24 detects a window signal from the transmitter and the received signal from the control switch 22. Similarly the correlation detector detects a code timing signal directly from the transmitter 20, as shown.

[0025] In Figure 3, the output of the transmitter is transmitted outside as a radio wave via an antenna unit which has a directivity. At the same time, the transmitter sends a timing signal indicating a window (hereinafter called "window signal") and a signal indicating the phase reference of a code to the receiver.

[0026] When the relationship between the phase reference of a code and the window is fixed previously, it is of course sufficient to supply just one of the two signals to the receiver.

[0027] Only while the transmitter is not implementing transmission, the receiver receives a radio wave and supplies it, after down conversion, as an input to a correlation detector like a matched filter, which is comprised of an acoustic surface wave element, for measuring cross-correlation with a transmitted code.

[0028] While the autocorrelation function of a window signal is ideally 1 when $\tau = 0$ and 0 otherwise, the window signal may show a non-negligible autocorrelation value depending on the scheme of forming the window signal, when $\tau$ is other than 0.

[0029] The utilization factor of transmission radio waves therefore varies for each phase of a code. As this utilization factor is predictable in advance, it can be compensated by adjusting the gain of the correlation detector or through digital processing after transmission.

[0030] Figure 4 exemplifies a case where the output signal of the receiver is compensated through digital processing. In this case, the output of the receiver 23 is transferred to a multiplier 30. An additional address is output from the transmitter 20 to a memory compensation value device 31 which is in turn coupled to the multiplier 30. The compensation output signal is obtained from the multiplier 30.

[0031] In Figure 4, the digital output signal from the

receiver is supplied to one input terminal of a multiplier. An output compensation value corresponding to each code phase, output from a memory, is supplied to the other input terminal of the multiplier in synchronism with a code timing signal output from the transmitter. A compensation output signal is computed as the multiplication output of the multiplier.

[0032] The output compensation value contains the autocorrelation value of the window signal that has been used in transmission. The output compensation value is so set as to be large when the autocorrelation value is high or the window is narrow, and to be small when the autocorrelation value is low, and serves to cancel the influence of the window size on each code phase.

[0033] Figure 5 exemplifies the constitution of a transmission signal in a case where FSK is used instead of PSK to constitute the transmission signal.

[0034] In Figure 5, the horizontal scale represents the time and either one of n types of frequencies and a signal-less state is assigned to each of m time slots ti.

[0035] The window signal that is denoted by "W" becomes 1 in a signal-less state and indicates that none of the n types of frequencies is not transmitted in this state.

[0036] In the period of W = 0, on the other hand, a signal of one of the frequencies, fj, is transmitted. The hatching in the diagram indicates the transmission state.

[0037] Since this radar apparatus can significantly increase the transmission time of radio waves as compared with the conventional radar apparatus designed for position measurement, the radar apparatus can exhibit an effect of reducing the peak power of transmission radio waves and is easy to handle.

## Claims

1. A random pulse type radar apparatus comprising:

   a transmitter for generating a hybrid type spectrum spread signal by simultaneously using two kinds of modulations which are phase shift keying (PSK) modulation for selecting a phase of a transmission radio wave in accordance with a pseudo noise digital code and outputting said transmission wave, and time hopping modulation for stopping transmission of a radio wave at random in accordance with said pseudo noise digital code;
   a receiving unit for selectively detecting an echo of a transmission signal radio wave, generated by said transmitter, from a target with a time delay;
   at least one a common antenna unit for use both for transmission and reception or antenna units installed close to each other and respectively serving single functional units; and
   a reception control unit for stopping an action of said receiving unit in a time zone in which said transmitter is outputting radio waves in accordance with said time hopping modulation,
   whereby a spatial distribution of an intensity of an echo of a transmitted radio wave is measured through computation of a cross-correlation function of a transmission signal and a reception signal.

2. A random pulse type radar apparatus comprising:

   a transmitter for generating a hybrid type spectrum spread signal by simultaneously using two kinds of modulations which are frequency shift keying (FSK) modulation for selecting a frequency of a transmission radio wave in accordance with a pseudo noise digital code and outputting said transmission wave, and time hopping modulation for stopping transmission of a radio wave at random in accordance with said pseudo noise digital code;
   a receiving unit for selectively detecting an echo of a transmission signal radio wave, generated by said transmitter, from a target with a time delay;
   at least one common antenna unit for use both for transmission and reception or antenna units installed close to each other and respectively serving single functional units; and
   a reception control unit for stopping an action of said receiving unit in a time zone in which said transmitter is outputting radio waves in accordance with said time hopping modulation,
   whereby a spatial distribution of an intensity of an echo of a transmitted radio wave is measured through computation of a cross-correlation function of a transmission signal and a reception signal.

3. The random pulse type radar apparatus according to claim 1, wherein as said hybrid type spectrum spread signal, a modulation state is determined by assigning a value of parallel data of two or more bits, obtained from values of individual sample points of PN (Pseudo Noise) code sequences of a binary or greater system, to a plurality of modulation states provided by adding a signal-less state added to individual phase states of phase shift keying (PSK).

4. The random pulse type radar apparatus according to claim 3, wherein a constant portion of a time zone where each modulation state assigned is maintained, is further assigned to a signal-less state.

5. The random pulse type radar apparatus according

to any one of claims 1 to 4, wherein a reception sensitivity or a reception signal level is compensated in accordance with a value of an autocorrelation function indicated by digital codes used in said time hopping modulation.

6. The random pulse type radar apparatus according to any one of claims 1 to 4, wherein a code sequence like a maximal linear code sequence (M-sequence) indicating an approximately constant autocorrelation value except when code phase matching occurs is used as digital codes used in said time hopping modulation.

FIG. 1

-PPP-PP-----N-NN-N--P-NNNPN----P--PN--N-N---P-NP-PNPN-NN-PP----NNN-PP--N-P-N---P
-N-P---P-NPP--N--N-N---P--PNP---P-PNN-PN-P-PNP-

FIG. 2

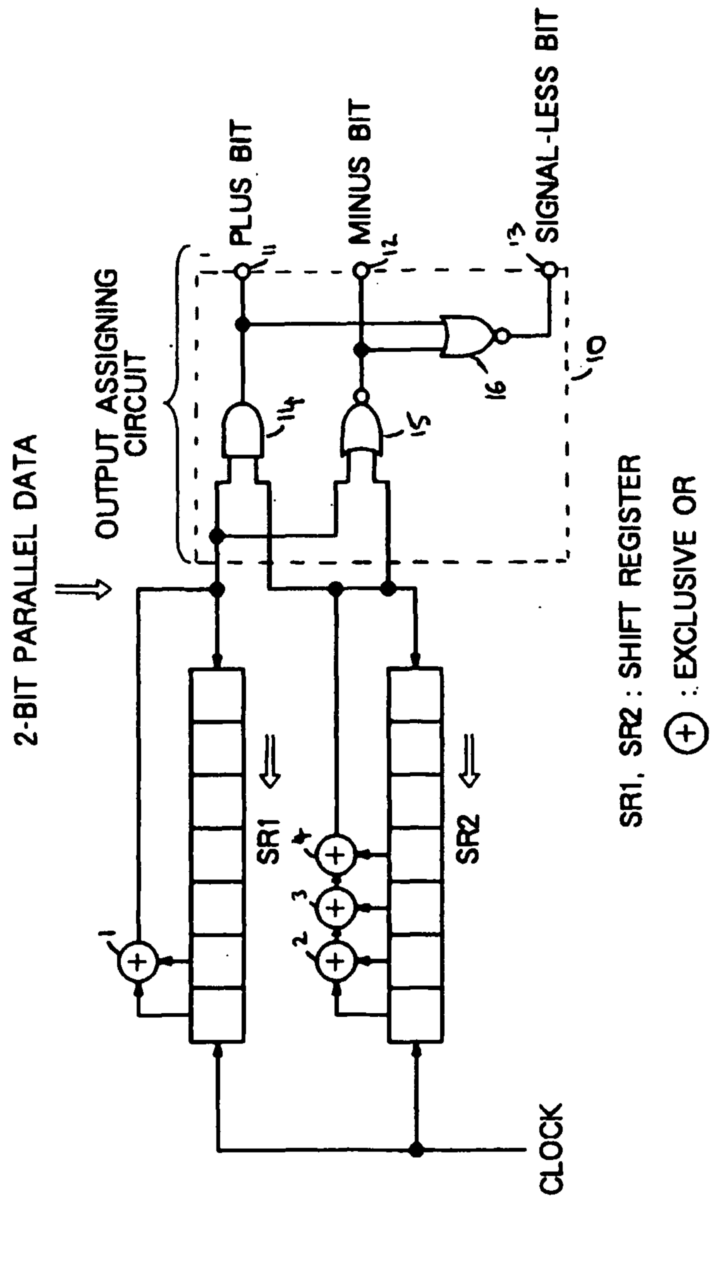

2-BIT PARALLEL DATA
OUTPUT ASSIGNING CIRCUIT
PLUS BIT
MINUS BIT
SIGNAL-LESS BIT
SR1
SR2
CLOCK
SR1, SR2 : SHIFT REGISTER
⊕ : EXCLUSIVE OR
1
2
3
4
11
12
13
14
15
16
10

FIG. 3

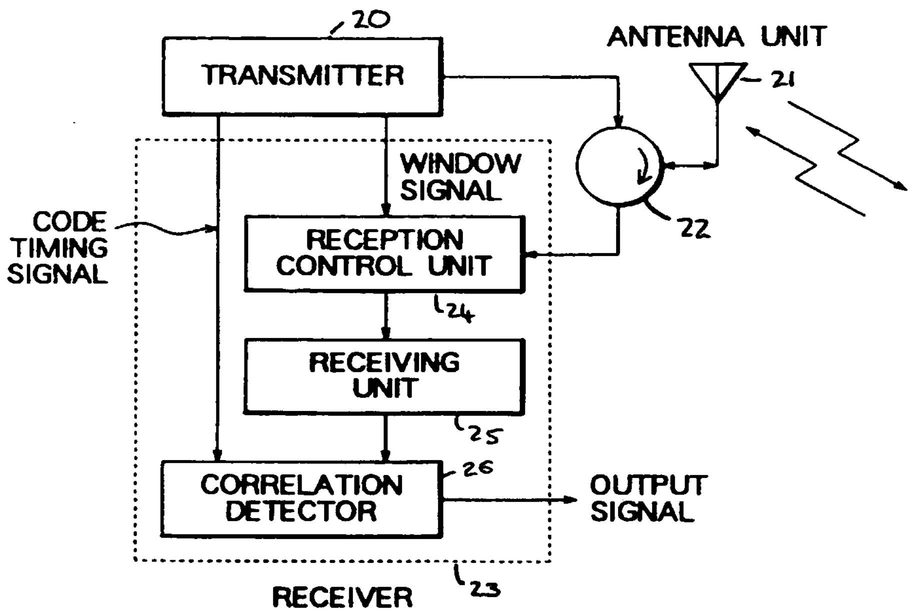

20
TRANSMITTER
ANTENNA UNIT
21
WINDOW SIGNAL
22
CODE TIMING SIGNAL
RECEPTION CONTROL UNIT
24
RECEIVING UNIT
25
26
CORRELATION DETECTOR
OUTPUT SIGNAL
23
RECEIVER

FIG. 4

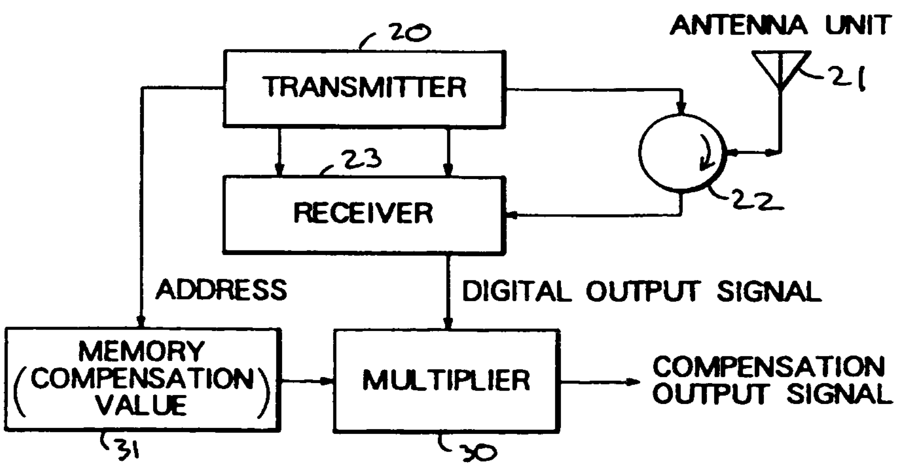
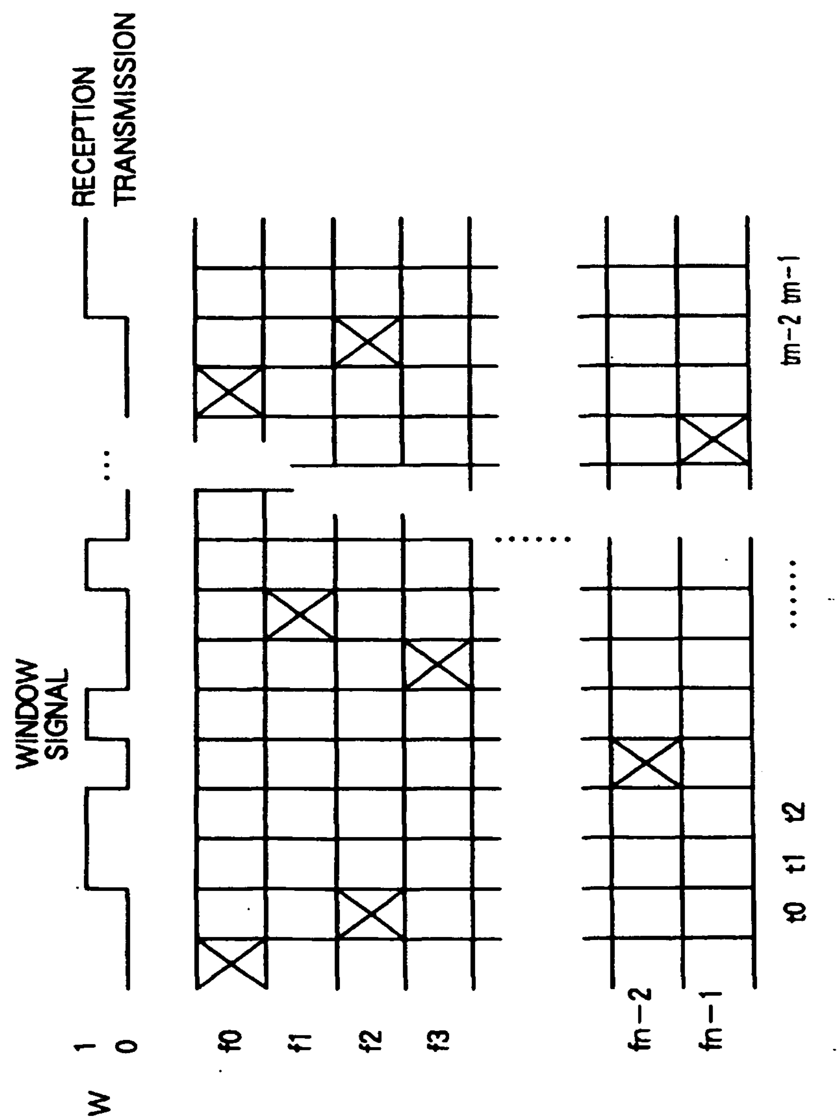
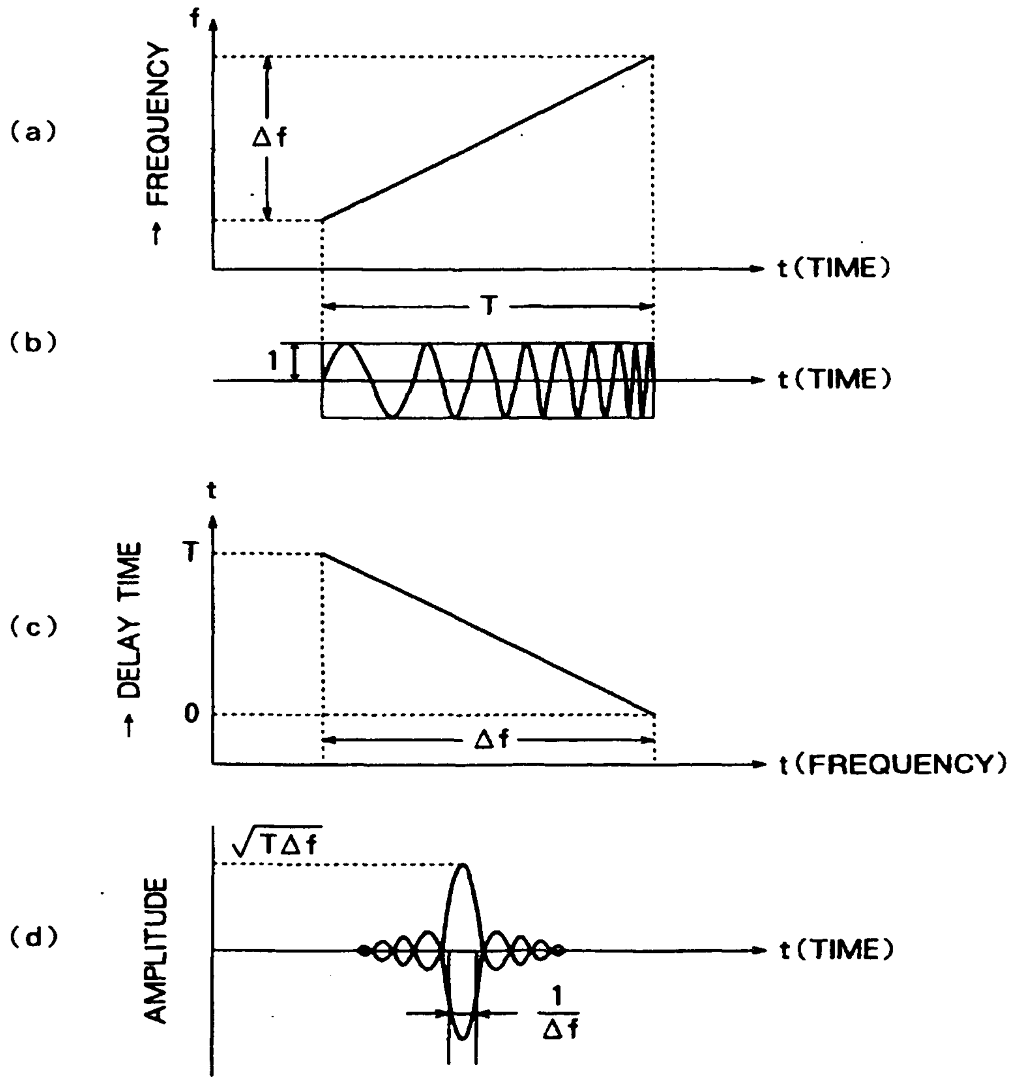

20
TRANSMITTER
ANTENNA UNIT
21
23
RECEIVER
22
ADDRESS
DIGITAL OUTPUT SIGNAL
MEMORY (COMPENSATION VALUE)
MULTIPLIER
COMPENSATION OUTPUT SIGNAL
31
30

FIG. 5


W
1
0
WINDOW SIGNAL
RECEPTION
TRANSMISSION
f0
f1
f2
f3
fn−2
fn−1
t0 t1 t2
tm−2 tm−1

# FIG. 6
PRIOR ART



# FIG. 7
PRIOR ART